EXTREME WIND EVENT OVER THE CANARY ISLANDS RELATED TO THE EXTRATROPICAL STORM DELTA: SENSITIVITY STUDY WITH A LIMITED AREA MODEL

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1. Introduction

On 28 November 2005 an extratropical storm with a warm core around 850 hPa affected the Canary Islands (Fig. 1) causing significant damage related to high sustained wind and intense gusts over some of the islands (Table 1). In this study we show the preliminary results associated with 27 configurations of the WRF-ARW local area model initialized with the 0.25º reanalysis of the ECMWF. Modifications in domain dimension and location, horizontal resolution, number of vertical levels and physics permit us to survey their impact in the wind solution. Highly non linear interaction of flow with topography was the main factor that produced gusts over 160 km/h at La Palma, 90 km/h at the coast in Tenerife, and over 215 km/h in its mountain top. Comparison of observations and model results shows the role of the warm core (Fig. 2) in the formation of an in phase and almost simultaneous hydraulic jump in the islands with the strongest orography, in a situation in which the position of the extratropical storm was not well situated (Fig. 3) even in the ECMWF reanalysis.

Fig.1. Tenerife and La Palma are the two islands with the strongest orography and were the most affected islands of the archipelago.

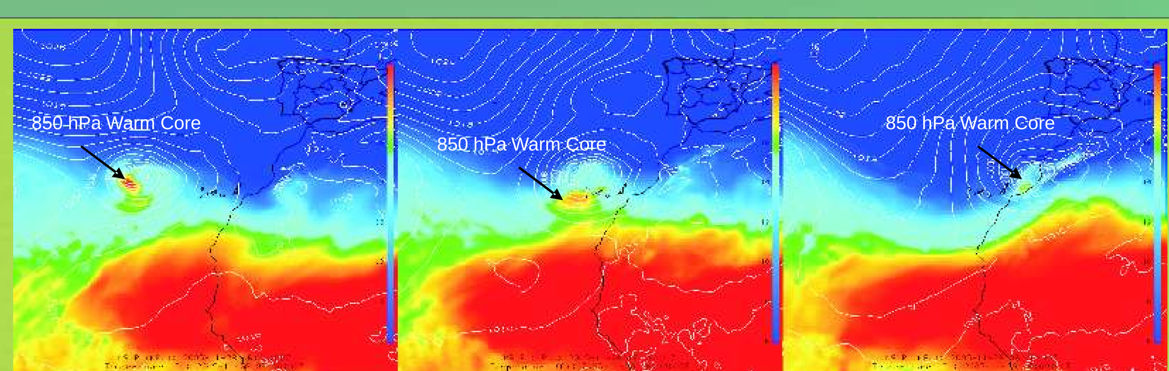


Fig. 2. ECMWF reanalysis of extratropical storm Delta showing the warm core in 850 hPa when going through the Canary Islands.

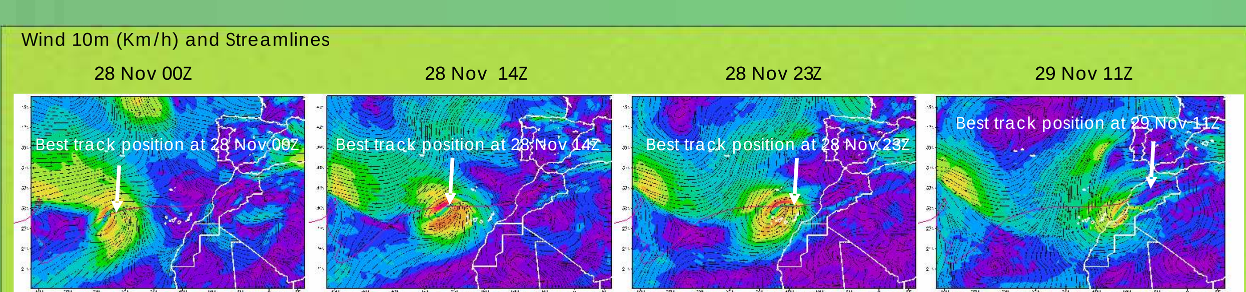


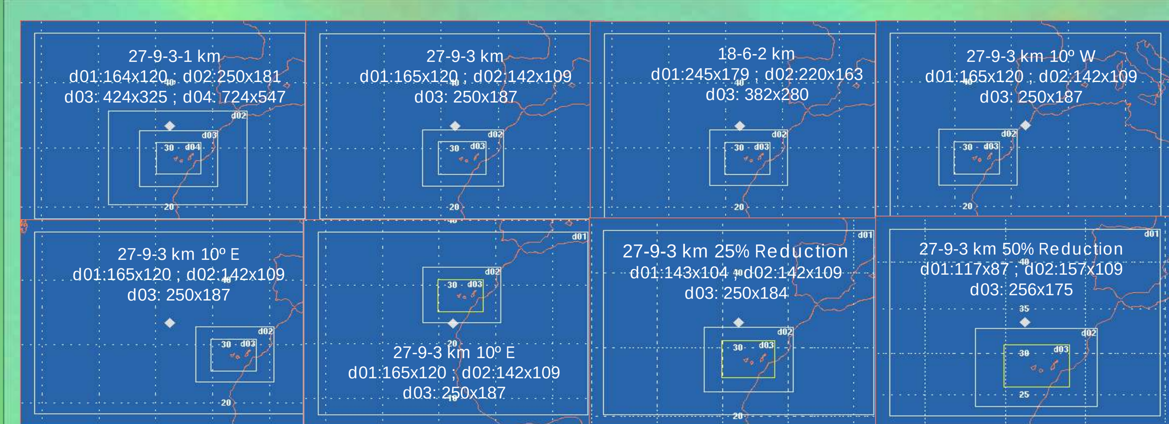
Fig.3. Evolution of Base Case simulation (27-9-3 km resolution, 31 levels and physics combination 5) driven by ECMWF LBC versus National Hurricane Centre Best Track, demonstrating an increasing out of phase evolution with time.

Station name	10 m wind speed (km/h)	10 m wind gust (km/h)	Time UTC 28 Nov 2005
Hierro airport	67	118	18:00
Tazacorte	31	59	12:30
La Palma airport	104	166	19:00
La Gomera	48	92	16:00
Tenerife north airport	30	70	16:00
S/C de Tenerife	57	132	21:00
Tenerife south airport	87	134	21:40
Izaña	180	218	20:00

Table 1. Wind speeds and gusts at 10 m in the principal observatories and airports of the archipelago.

2. Method: numerical modelling setup

To explore their impact in the numerical solution we have designed several non hydrostatic experiments taking into account geometrical factors, like the size and position of the mother domain, number of nested grids, horizontal resolution and number of vertical levels (Fig. 5); and physical parameterizations (Fig. 6). To specify the size of the mother domain we have used HYSPLIT backward trajectories (Fig. 7 and 8) to evaluate the propagation of the advective lateral boundary condition error at several levels. The 31 level WRF-ETA scheme has been interpolated to obtain the 41 and 61 level distributions. The size of the mother domain has been positioned 10º S, 10º E y 10ºW in relation to the base case configuration, and a reduction of 25% and 50% has also been applied to the centred case. Twelve combinations of physical schemes has been obtained using 3 microphysics, 2 surface layers, 2 boundary layers and 2 cumulus options. Non-nested domains have been defined to resolutions of 2 km, 3 km, 6 km, 9 km and 27 km. An additional hydrostatic case forms a cluster of 27 experiments to explore the variability of the numerical solution.



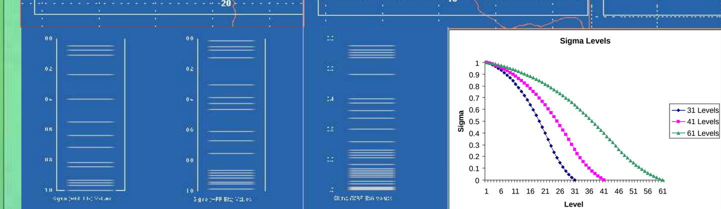


Fig. 5. Domain geometry configurations and vertical level distributions. The bigger domain configuration (27-9-3-1 km 61 levels) runtime was more than 20 hours in the MareNostrum Supercomputer of the Barcelona Supercomputing Centre using 512 processors.

microphysics options
1.b) Lin et al.
1.c) WSM 3-class simple ice
1.e) Ferrier (new Eta) microphysics
surface-layer option
3.1.a) Monin-Obukhov
3.1.b) Monin-Obukhov (Janjic Eta)
boundary-layer option
4.a) YSU scheme
4.b) Mellor-Yamada-Janjic (Eta) TKE
cumulus option
5.a) Kain-Fritsch (new Eta)
5.b) Betts-Miller-Janjic

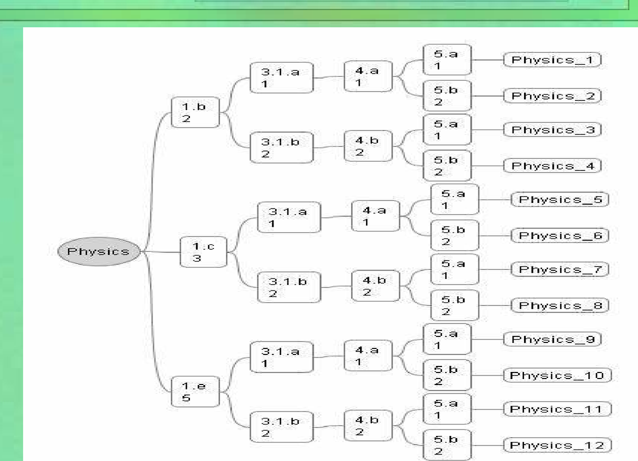


Fig. 6. Combinations of WRF-ARW physics schemes used.

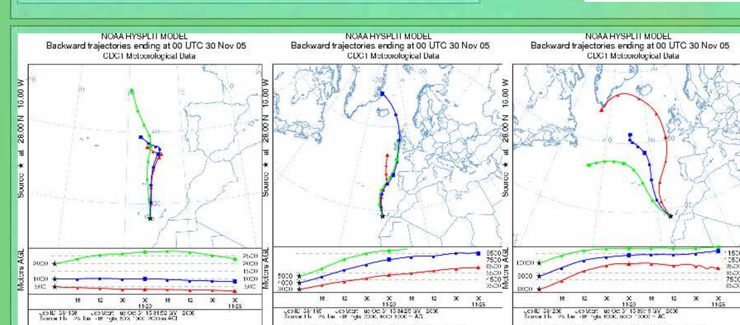


Fig. 7. HYSPLIT backward trajectories at several levels used to evaluate the size of the mother domain to diminish the effect of LBC advective errors in 48 forecast hours.

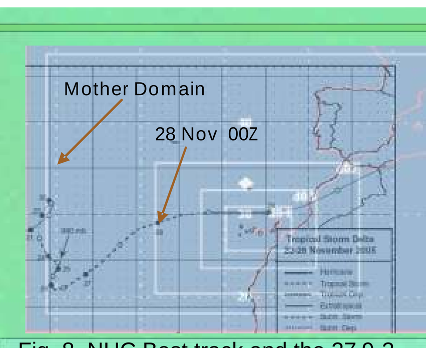


Fig. 8. NHC Best track and the 27-9-3-1km multiple nested grid case. Initialization on November 28th 00Z guarantees a well posed lateral boundary condition configuration.

3. Results

Spaghetti plots (Fig. 9) for 850 hPa temperature (a) and 1000 hPa geopotential (b), and 10 m velocity standard deviation (c) show the variability of the solutions. RMSE and BIAS of the experiments (Fig. 10) using reanalysis and observations were grouped taking into account resolution, number of levels, domain position, domain size reduction, physics and hydrostaticity. Only the most relevant plots are shown. A selection of the stations located in the most affected islands were used to plot all the numerical cases versus the observations (Fig. 11). Velocity and specific humidity vertical sections at the latitude of the wind velocity peak in Tenerife are presented for several resolutions (Fig. 12-a). A 3-D vertical and horizontal section through the two points of maximum velocity in La Palma and Tenerife is shown (Fig. 12-b). IR satellite images, reanalysis sea level pressure and 850 hPa temperature are presented (Fig 13-a). Mean Froude number is calculated in the layer 1,7 km to 2,7 km (Fig. 13-b).

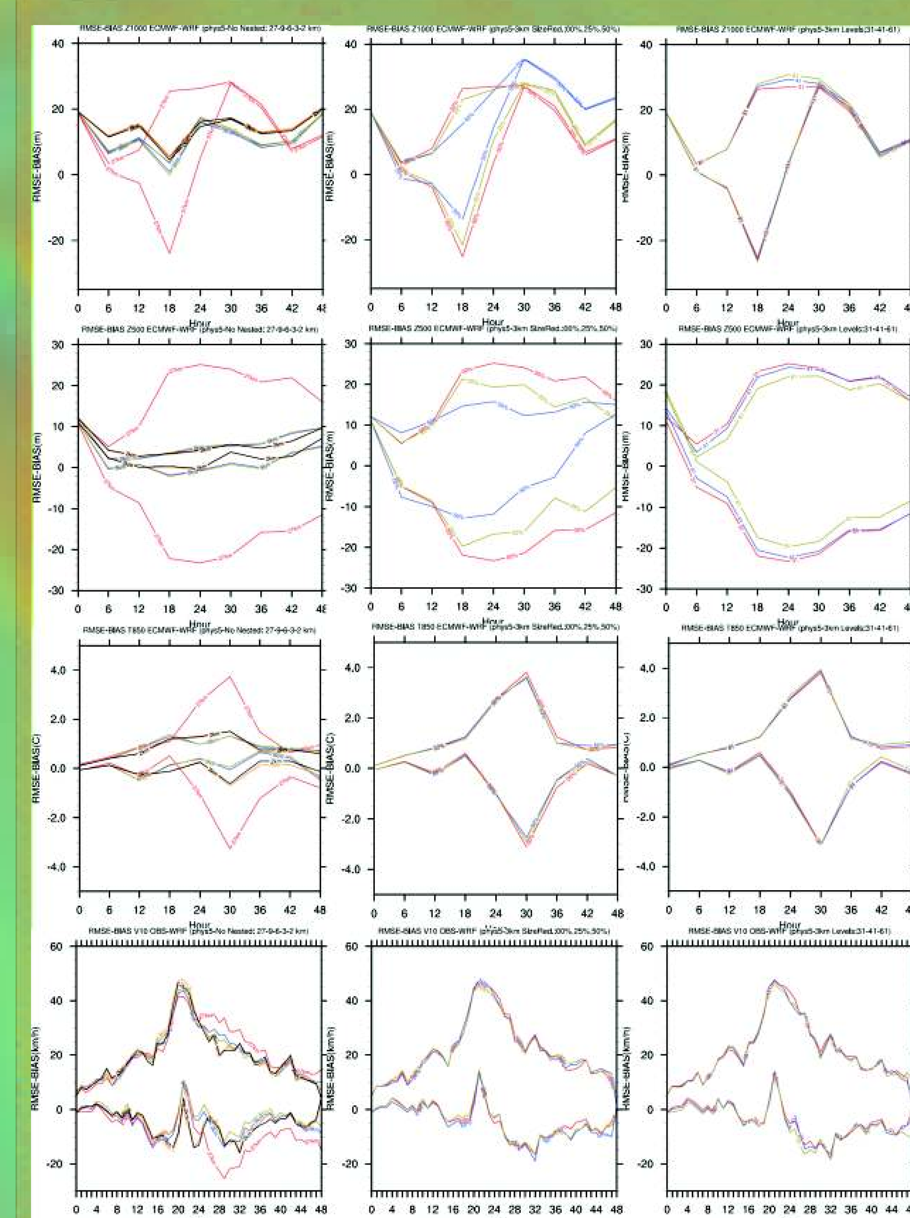


Fig. 10. Some of the RMSE and BIAS comparisons demonstrate the impact of the configurations in the solution. In this figure we have grouped the curves taken into account the resolution and size (no nested domains), and the number of levels.

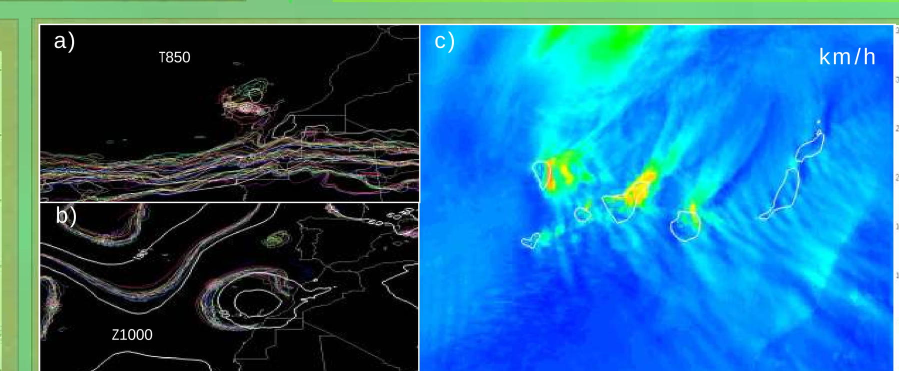


Fig. 9. All cases spaghetti plot for 850 hPa temperature (a), 1000 hPa geopotential (b) and 10m wind standard deviation (c) at 21Z on 28/11/2005.

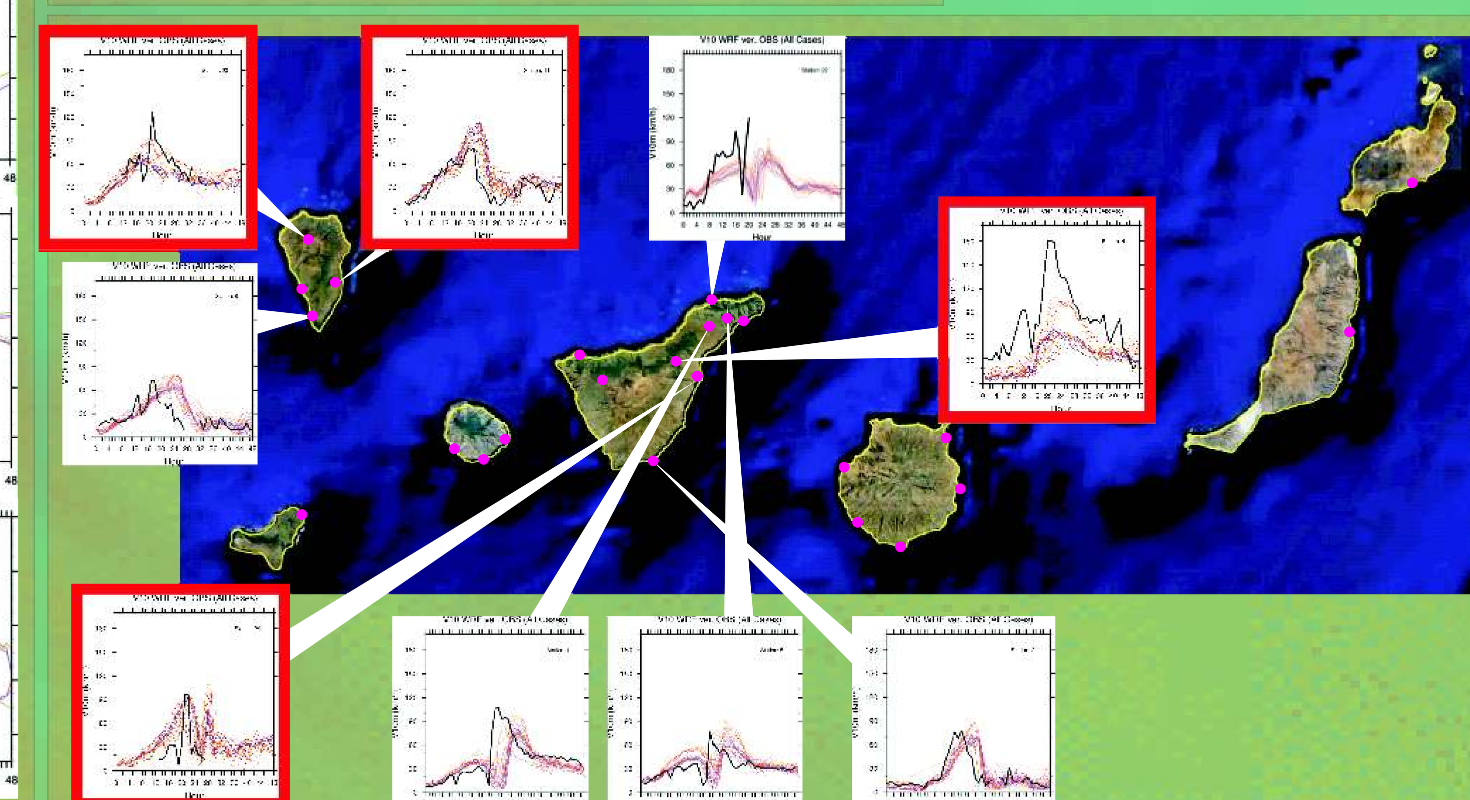


Fig. 11. Wind velocity at 10 m for observation and numerical model results has been plotted for some of the stations of the two most orographic islands. A generalized delay in wind maximum is observed at almost all the stations. No delay was observed in only 4 stations, situated at the mountain lee side and at the tops.

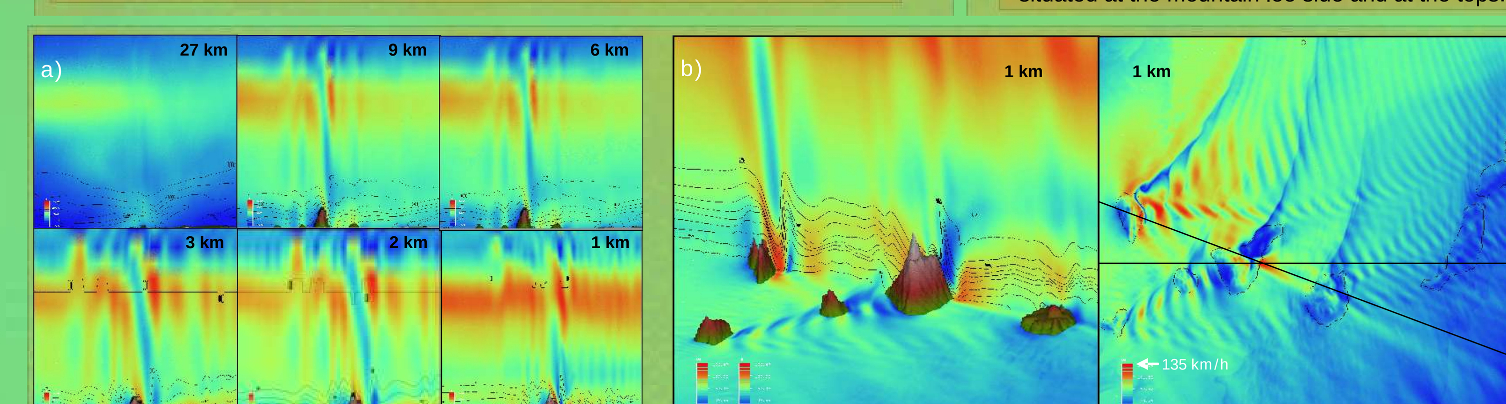


Fig. 12. The six panels in a) show the influence of the resolution in the development of the hydraulic jump in Tenerife, with a vertical section situated in the latitude of maximum 10 m wind registered. Panel b) shows a diagonal vertical section passing through the 10 m velocity maximum at La Palma and Tenerife using the 1 km and 61 levels experiment. Wind velocity and specific humidity are presented in both panels.

4. Discussion

Certain variability is observed in the numerical results due to the change in configurations. Most differences are observed in association with resolution and domain position and size. Smaller domains are in better accordance with reanalysis which provides lateral boundary conditions. Higher resolutions increase agreement with observations located in places affected by downslope winds associated to mountain wave breaking. Not much differences were observed increasing number of levels. Physics combination 12 had the best reanalysis RMSE-BIAS with no significances observed in the observational ones. Numerical results in almost all the observation locations show a wind velocity peak delay of 3 to 5 hours. Only 4 locations situated on mountain leeside and top of La Palma and Tenerife (red frames in Fig. 11) are almost in phase with the maximum velocity, depending on the configuration. Best Track of NHC showed a delay in ECMWF reanalysis storm position. In contrast, it appears that there was not such a delay in the warm core position. Mean Froude number shows values around 1 associated with the warm core crossing, causing an hydraulic jump in numerical results in phase with observations. Further work is required to understand the role of warm cores in in this type of storms in places with steep orography. Future studies will focus on other strong wind cases with and without warm core interacting with Canary Islands orography.

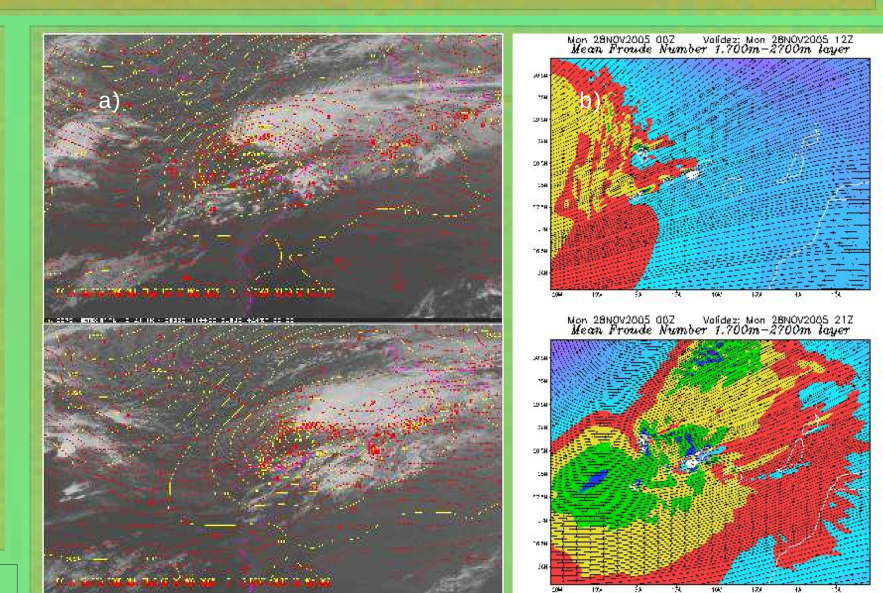


Fig. 13. (a) Sea level pressure and 850 hPa temperature over IR satellite image at 18Z and 24Z on 28/11/2005. (b) Mean Froude number in layer from 1.700 m to 2.700 m at 12Z and 21Z on 28/11/2005.

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